

GEORGE P. MERRILL

MAY 19 1901

DEPT OF GEOLOGY

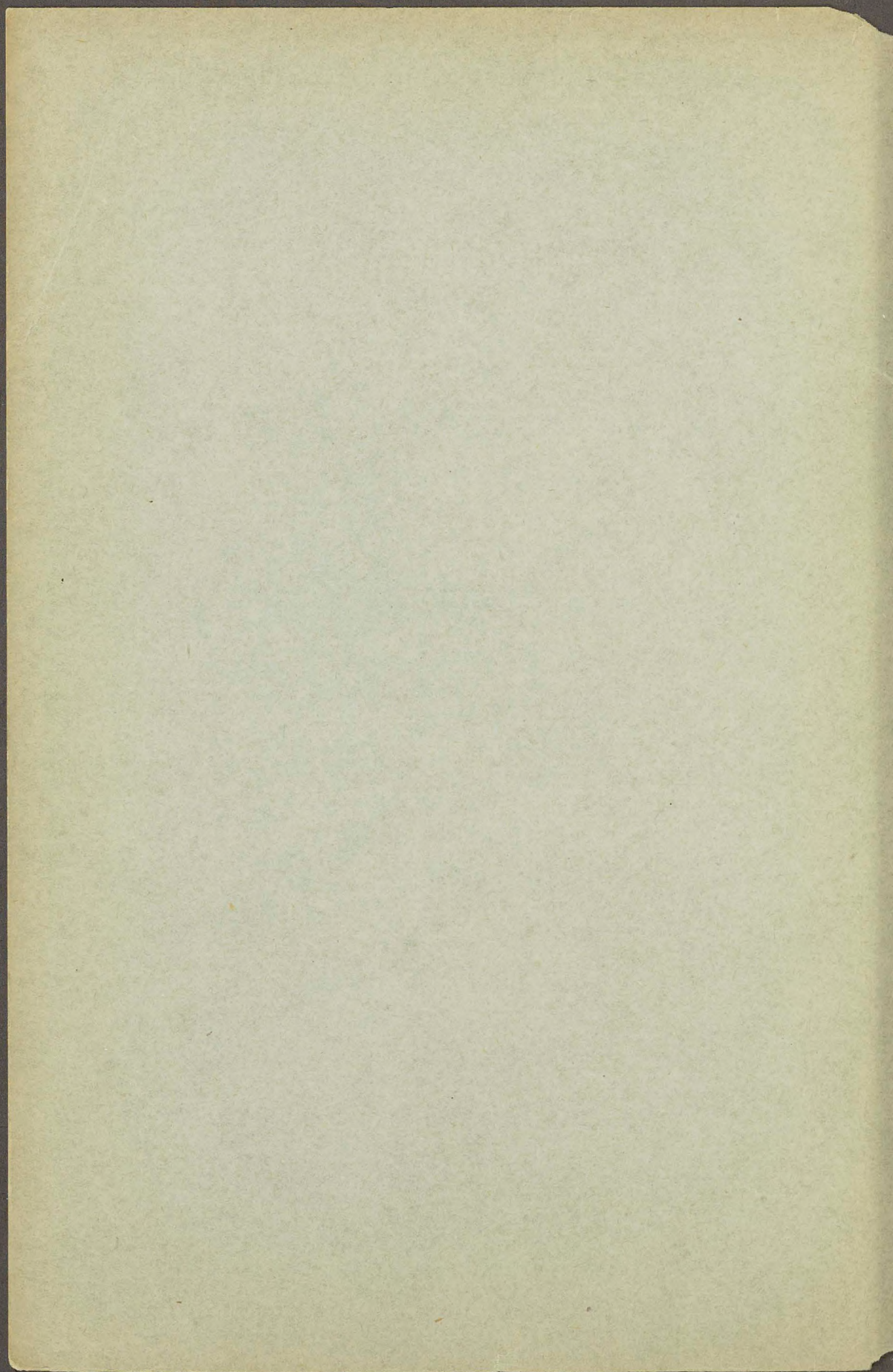
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CONTRIBUTIONS FROM THE GEOLOGICAL DEPARTMENT
OF COLUMBIA UNIVERSITY.
VOL. IX. No. 78.

The Serpentine of Manhattan Island
and Vicinity and their Accom-
panying Minerals.

D. H. NEWLAND.

SCHOOL OF MINES QUARTERLY, April, 1901, p. 307; July, 1901, p. 399.



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Reprinted from THE SCHOOL OF MINES QUARTERLY, Vol. XXII, April, 1901, No. 3.

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THE SERPENTINES OF MANHATTAN ISLAND AND VICINITY AND THEIR ACCOMPANYING MINERALS.

By D. H. NEWLAND.

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Introduction.—Since Mather first described the serpentines near New York and ventured to deal with their genetic relations by classifying them in his "Trappean Division," they have been the subject of frequent discussion by geologists working in this field. The view expressed by Mather that the serpentines were modified forms of eruptives has until recently met with little favor. The reason

for this divergence of opinion is to be found, no doubt, in the fact that the methods now used in the study of such questions had not been developed at that time, and too much importance was placed on general characters and appearance in the field. In 1890, G. F. Merrill published a description of the serpentine from Aqueduct Shaft 26, New York City,* which appears to be the first paper giving any information as to the microscopic nature of the rocks and the first to definitely trace their origin. His researches, however, did not extend beyond this locality.

A paper by F. J. H. Merrill † entitled "The Geology of the Crystalline Rocks of Southeastern New York," is also of importance in this connection. Dr. Merrill briefly outlines the general progress that has been made in the study of serpentines during the past few decades, and describes the New Rochelle area, whose serpentine, he shows is derived from pyroxene and amphibole. The igneous theory of origin first advanced by Mather is once more brought to notice and used with reference to this locality. Dr. Merrill states that he found no direct evidence bearing on the genesis of the Hoboken, Staten Island and Rye serpentines.

DISTRIBUTION OF THE SERPENTINES.

The serpentines are exposed in a series of roughly lenticular areas that reach in a broad curve through Hoboken, Manhattan Island and New Rochelle to a point near the village of Rye, which is some thirty miles northeast of Staten Island. All show more or less elevation relative to the surrounding formations, this feature being very marked in the two localities first mentioned. It is to be noted that these rocks are included in a narrow belt of related types, which extend with brief interruptions from Maine to northern Alabama.

FOOTNOTE. The field work and the greater part of the investigation upon which this paper is based were carried out during the fall of 1896, and the following winter, while the writer was Fellow in Geology at Columbia University. A summary of the principal results was given before a meeting of the New York Academy of Sciences in May, 1897. The writer desires to acknowledge his indebtedness to Dr. Arthur Hollick for information as to the Staten Island localities, to Mr. G. A. Goodell for chemical analyses of the rocks, and especially to Professor I. F. Kemp, who gave advice and assistance in the preparation of the paper and placed the facilities of the Geological Department at his disposal.

* "Notes on the Serpentine of Essex County, New York," etc., *Proceed. U. S. Nat. Mus.*, Vol. XII., pp. 595-600.

† New York State Museum Report, 1896.

THE STATEN ISLAND SERPENTINE.

Geological Features.—The serpentine outcrops at numerous localities, but, so far as known, only within the bounds of the central elevated area that forms such a prominent topographic feature of the Island. This ridge starts at the northeastern end, and follows the shore line for about two miles. It then extends in a south-westerly direction somewhat beyond Richmond. It is a lense-shaped mass having an extreme length of about seven miles and a width of two and a half. The total area is not far from thirteen square miles.

The northern and eastern limits of the ridge are marked by steep and, in places, precipitous slopes, but to the south and west the contours widen out, and its extent in these directions can not be accurately defined. According to Bien's topographic map, the greatest elevation above sea level is a little over 400 feet, while a considerable area is above the 200 foot contour. The surrounding plain ranges from tidewater to 80 feet above.

The surface of the ridge is broken by low hills and rather wide valleys that have been rounded out by weathering and denudation. In places a heavy covering of drift in the shape of clay and gravel with occasional boulders of diabase, sandstone and gneiss is present, but it often gives way to a thin coating of humus resting directly upon the rock. It is noteworthy that plant growth is abundant and of good size, notwithstanding the usual unfertility of lands derived from magnesian rocks.

Between the ridge and the eastern shore is a belt of low-lying country composed of Cretaceous clays, morainal material and beach sand. Toward the south these deposits widen out and extend across the Island in a westerly direction. The Cretaceous strata sometimes exhibit evidences of violent disturbance, being crumpled and folded like rocks that have been subjected to mountain-making forces. This phenomenon has been studied by Dr. Hollick, to whose paper reference should be made for a full description and explanation.*

Triassic sandstone borders the serpentine on the west, but the line of contact is not revealed by outcrops or noticeable physiographic features. The sandstone is broken through at some distance from the serpentine by a parallel dike of diabase.

* "Dislocations in Certain Portions of the Atlantic Coastal Plain Strata and their Probable Causes." Trans. N. Y. Acad. Sci., XIV., pp. 8-20. 1894.

It is probable that the sandstone and clays rest upon schist, in a southern continuation of the rocks exposed on Manhattan Island which are regarded as metamorphosed strata of Hudson River age. Cozzens* has recorded an interesting occurrence of pegmatite granite at Quarantine near Tompkinsville, that is now inaccessible. The same locality is described by Britton,† as follows: "Fine granite outcrops on the shore of the Upper New York Bay, about four hundred feet southwest of the Tompkinsville steam-boat landing, and directly in front of the old building known as Nautilus Hall. The surface of the rock exposed at low tide is about eighty feet wide by fifty feet long, at high water mark the rock disappears beneath a hill of drift some fifteen feet in thickness. A little more of the same rock is exposed at a point about two hundred feet south of the main outcrop." Pegmatite veins or dikes are of frequent occurrence in the mica schist formation of Manhattan Island and in places are of considerable extent.

General Characters.—A macroscopic examination of typical specimens shows little else than serpentine. Usually a few crystals or bunches of chromite and scales of talc and chlorite are visible, but these minerals are relatively unimportant.

On the eastern slope of Pavilion Hill, the rock is given a special character by the inclusions of amphibole crystals, usually of light gray color and prismatic habit. They form a network of interlacing fibers which at times entirely replaces the serpentine. This rock is also developed further south near Grant City and it is probably present along the entire eastern border. Its presence is marked by sharper contours in the topography, the rock being much more resistant to erosion and weathering than serpentine.

Other variations from the normal type are represented by talc and chlorite schists, thin bands of which accompany the tremolite.

The color of the serpentine varies with the amount of iron oxides present and the degree of weathering which it shows. Normally, it is dark-green or almost black upon fresh surfaces. Weathering is first manifested by oxidation of the iron constituents which stain the rock yellow or reddish. Following this, bleaching effects are noticeable with a decrease in hardness. The final product is a soft, white, powdery mass much resembling talc. Specimens from

* "A Geological History of New York Island," 1843.

† N. L. Britton, Geology of Richmond Co. SCHOOL OF MINES QUARTERLY, II., 165.

Castleton Corners have a mottled appearance, owing to the bronze-colored inclusions in a groundmass of very dark serpentine.

A more or less well defined lamination is apparent wherever the rock has been exposed to weathering influences for any length of time. Pronounced schistose types do not occur, however, except on the edges of the area.

Jointing is everywhere present, but it shows little regularity even within the limits of a single outcrop. At Grant City, the most marked system has a nearly east and west strike with a steep dip of 70° to 80° . Usually the rock is divided into masses of irregular size and shape by the numerous joints. The surfaces are slickensided and striated, showing that the rock has been subjected to pressure. This may have been due to some extent to the increase in bulk by alteration of the original minerals, though it can hardly be believed that the intense crushing effects observed at many of the localities could have been produced by such an agency. It is noticeable that within the interior the serpentine is much less disturbed. At Castleton Corners, a faint parallel arrangement of the constituents is observable on weathered faces, but otherwise the appearance is similar to that for massive igneous rock. The strongest developed system of jointing here has a N.W.-S.E. direction.

Microscopic Characters.—An examination of thin sections shows that the processes of alteration have been carried nearly to completion. In the majority of cases only secondary minerals are present, including iron ores, carbonates, chlorite and talc, besides varieties of serpentine which are the most important. Fortunately the characteristic textures resulting from the change of the primary minerals to serpentine are often well preserved and give a clue as to the derivation of the latter, when studied and compared with the results recently achieved in this petrographic field.

One of the most interesting types, microscopically, is that found near Castleton Corners, where in excavating for the foundations of a building, the rock has been exposed to a depth of several feet. The precise locality is known as "the old Germania Brewery site." Compared with specimens from other parts of the area, it has suffered very little from secondary alteration. Glistening bronze prisms embedded in a ground mass of dark serpentine lend a striking resemblance to some of the basic types of gabbros. The prisms have a good cleavage parallel to the longer axis.

In thin section the serpentinous groundmass breaks up into an interwoven mass of fibers and plates sprinkled with dust and larger particles of iron ores. The fibers are slightly pleochroic, yellow to light green in transverse sections and give low polarization colors of the first order. The prismatic individuals are built up from serpentine plates in parallel arrangement, which give aggregate extinction. They are also slightly pleochroic and bi-refrident. Their whole appearance is strikingly similar to bastite, and it was suspected at first that they were pseudomorphs after orthorhombic pyroxene. Examination of fresher material, however, revealed included remnants of a colorless mineral whose optical properties correspond to monoclinic *amphibole*. The prisms are of stocky habit, measuring about 20 mm. in length by half that or more in width. Cleavage is pronounced in the longitudinal direction, while a cross fracture at right angles is often present. The boundaries in the prism zone are sharp, the ends, however, irregular and feathery, losing themselves in the surrounding serpentine. By alteration the amphibole assumes a faint yellow color from inclusions of serpentine and gradually changes its optical properties. The process of serpentinization is simple and uniform in all cases. In the first stages, minute veinlets of serpentine are developed along the cleavage planes of the amphibole at the ends. From here they gradually extend toward the center, at the same time reaching out into the lateral prisms and widening out until the crystal is entirely altered. By this process serpentine plates are developed with uniform arrangement parallel to the *c* axis of the amphibole. In transverse sections the plates are divided into two sets which cross each other at angles corresponding to the hornblende cleavage. When examined in convergent light, cleavage pieces show the emergence of an optical bisectrix with large axial angle. The serpentinization is accompanied by separation of magnetite dust.

A colorless monoclinic *pyroxene* was observed in one of the specimens from this locality. It occurs in granular aggregates representing partially serpentinized crystals whose original boundaries are not distinguishable. The high bi-refridence, large angle of extinction (0° – 37°) and prismatic cleavage renders its identification very easy. As with the amphibole, alteration begins by the formation of serpentine along the edges and cleavage planes. When completed, a mass of fibers and plates occupies the position

of the former crystal. They show no uniform arrangement as a rule, though within certain limits they may be parallel or may cross each other at a definite angle. Very little magnetite is set free by the alteration.

Chromite in irregular grains and aggregates, rarely in octahedra is quite abundant in all the specimens from this locality. It is usually quite opaque and difficult to distinguish from magnetite.

Chlorite and *talc* are persistent but not important secondary products. Both minerals occur in thin blades which are distributed

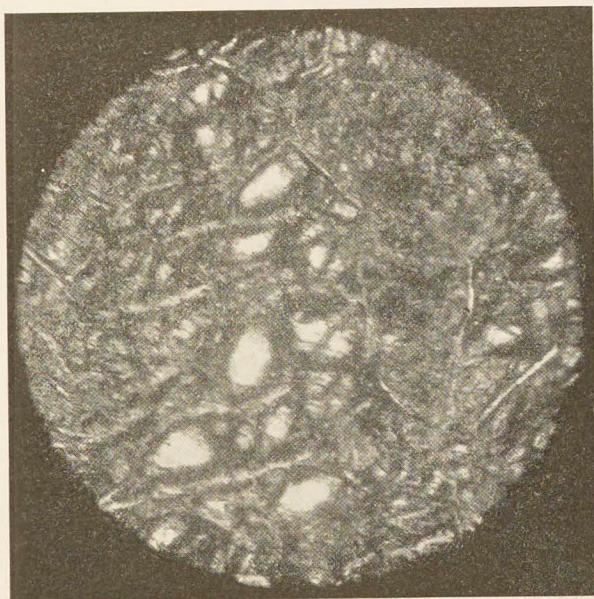


FIG. 1. Serpentine from Staten Island, showing partially altered crystal of olivine with automorphic boundaries.

through the serpentine. Apparently they have been derived from both amphibole and diopside.

At Martling's Pond, about one mile northeast from Castleton Corners, there is an outcrop of serpentine showing similar macroscopic characters to that just described, but with different structure of the ground mass. This peculiarity is important in that it affords evidence of the former presence of *olivine* in considerable quantities. Altered fragments and, in a single case, a crystal of this mineral were also found in some of the freshest material. The crystal

(Fig. 1) shows the prismatic development with pyramidal terminations characteristic of olivine, gives parallel extinction and rather high polarizing effects. By alteration, the olivine yields serpentine fibers that are so arranged as to give a reticulate appearance to the field. Small veins or threads of dark serpentine that polarizes quite strongly and contains abundant magnetite, surround lighter areas of so closely matted texture that they have little effect on polarized light. Several of these areas may be grouped together representing the space formerly occupied by an olivine

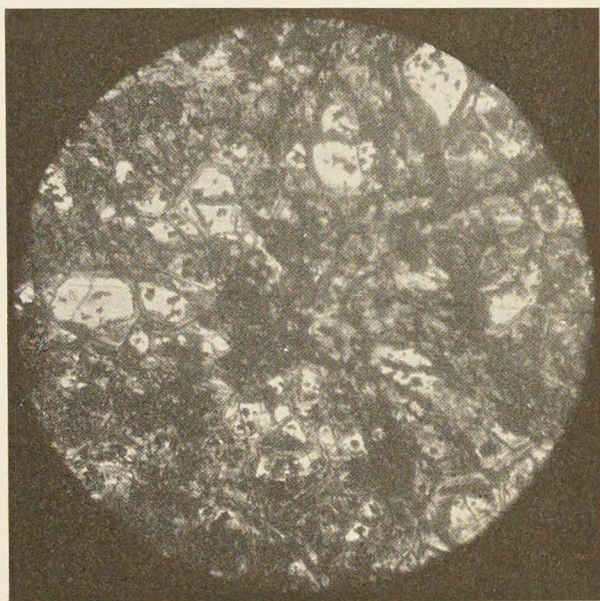


FIG. 2. Serpentine from Staten Island, completely altered. The lighter areas were formerly occupied by olivine crystals and the original boundaries of the latter are till discernible.

crystal. This peculiar structure is conditioned by the processes of alteration which begin on the outer edge of the olivine and along the lines of fracture; during the first stages, the serpentine substance has opportunity to assume a definite arrangement, but later on apparently the conditions for crystallization are not so favorable. When well defined, the structure affords indubitable proof of the former presence of olivine. By secondary alteration, that is, by the weathering of the serpentine, and by the removal of the iron ores, the characters are gradually erased, and a homogeneous mass results which gives little or no clue as to its genesis.

Pavilion Hill, near Tompkinsville, affords the most extensive outcrop of the rock and is interesting from the variety of its types. This locality is on the extreme northeastern edge and not far from the pegmatite granite described by Britton. The hill on its eastern face has a very steep slope for some distance, and is formed by bare rock. One variety is a hard, dense mass of tremolite crystals, thinly laminated and apparently resting on edge. Under the microscope it shows little that is worthy of note, being composed almost entirely of thin needles of tremolite in a perfectly fresh state. In close proximity is a dark, massive, completely altered serpentine that is sprinkled with silvery flakes of talc and that contains chromite and magnetite. This rock seems to have been derived largely from amphibole and olivine (Fig. 2). The variety most commonly met is dark-green and nearly massive. It is composed of serpentine, talc, chlorite, iron ores and tremolite.

Talc schist and chlorite schist are developed along with the tremolite rock and their association is probably a genetic one. The best exposure is at Grant City in a shallow ravine just west of King's Highway. The chlorite forms a thin band that is included in tremolite schist. It has become very soft and friable through weathering. In thin section it shows blades of low refracting chlorite, with almost no binding material. The blades have strong pleochroism, dark bluish-green to yellow, and small axial angle. The talc schist offers little of interest from a microscopic standpoint, though its exact relation to the serpentine and tremolite rock would be well worth determining. The occurrence of these secondary phases of alteration on the border of the area naturally suggests an igneous contact.

Chemical Composition.—The general character of the serpentine is illustrated by the following analysis of a specimen from Castle-ton Corners, which was made by Mr. G. A. Goodell:

SiO ₂	36.72	MgO	29.09
Al ₂ O ₃	1.06	CaO	9.95
Fe ₂ O ₃	6.59	H ₂ O below 110° C.	0.52
Cr O ₃	0.49	H ₂ O above 110° C.	14.02
FeO	1.53		14.50
		Total	99.97

From the relatively large amount of ferrous iron present, it is seen that the material could have suffered but little secondary alteration. This is in agreement also with the percentages of water

and carbon dioxide found. On the assumption that all of the water is united in the serpentine, the proportion of this mineral to the total mass is about 4 to 5.

THE HOBOKEN SERPENTINE.

Geological Relations.—This area lies about seven miles from the northern extremity of the Staten Island serpentine and nearly in its line of strike. It forms a low, oval prominence known as Castle Point that reaches slightly out into the Hudson River. The east-

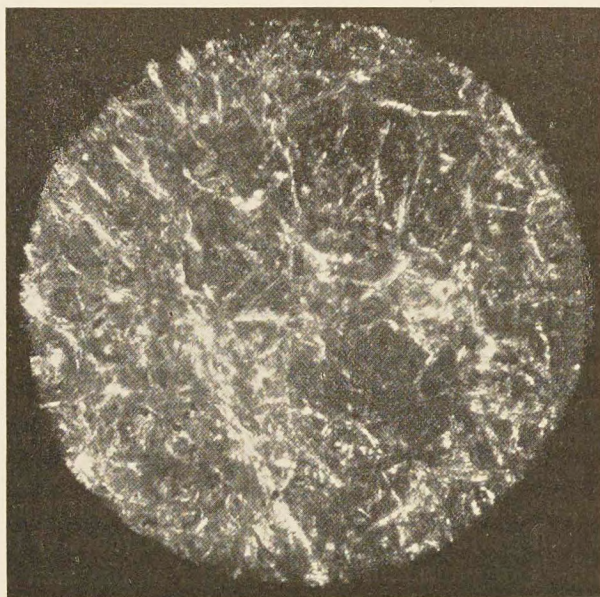


FIG. 3. Serpentine from Hoboken, a structureless mass of serpentine fibres.

ern edge has been cut away by blasting and the rock is exposed for a distance of several hundred feet. The highest point of the prominence is some 60 or 70 feet above the river, but a sharp slope on all sides soon carries it to the level of the surrounding deposits which are only a few feet above the high-water mark. Cook mentions that the rock was found by drilling about one-fifth of a mile north of the exposed area at a depth of 175 feet. The geological position of the mass is similar to that of Staten Island, being in contact with gneiss on the east and overlain by Triassic sandstone on the west.

General Characters.—In general appearance the serpentine re-

sembles that found at some of the localities on Staten Island. It is usually light green in color, rather soft and of granular texture. Evidence of disturbance is shown by the frequent and irregular jointing, which gives it a brecciated appearance and in the slicken-sided surfaces. The joint-fissures are frequently filled with vein serpentine and the surfaces are covered with a film of carbonates. Octahedra and aggregates of chromite are abundant.

The rock is thoroughly serpentinized throughout. No traces of the original silicates could be found in any part of the exposure.

Microscopic Characters.—Microscopically, the serpentine is similar to the more altered types of Staten Island, particularly those occurring near Grant City and northward. It is composed of fibers and blades in irregular or approximately parallel arrangement, but without any of the well-defined structures described in the previous pages (Fig. 3). The fibers are sometimes strongly pleochroic and show a change of color that suggests chlorite, ranging from dark green with a bluish tint to yellow. A partial alteration to this mineral in such cases appears probable. The bladed variety gives a biaxial interference figure in convergent light with a variable axial angle.

A peculiar microscopic feature is the presence of colorless, low-polarizing bands, which cut across the field in continuous lines independently of the arrangement of the serpentine units. Their bleached appearance suggests that they may represent the course taken by percolating waters.

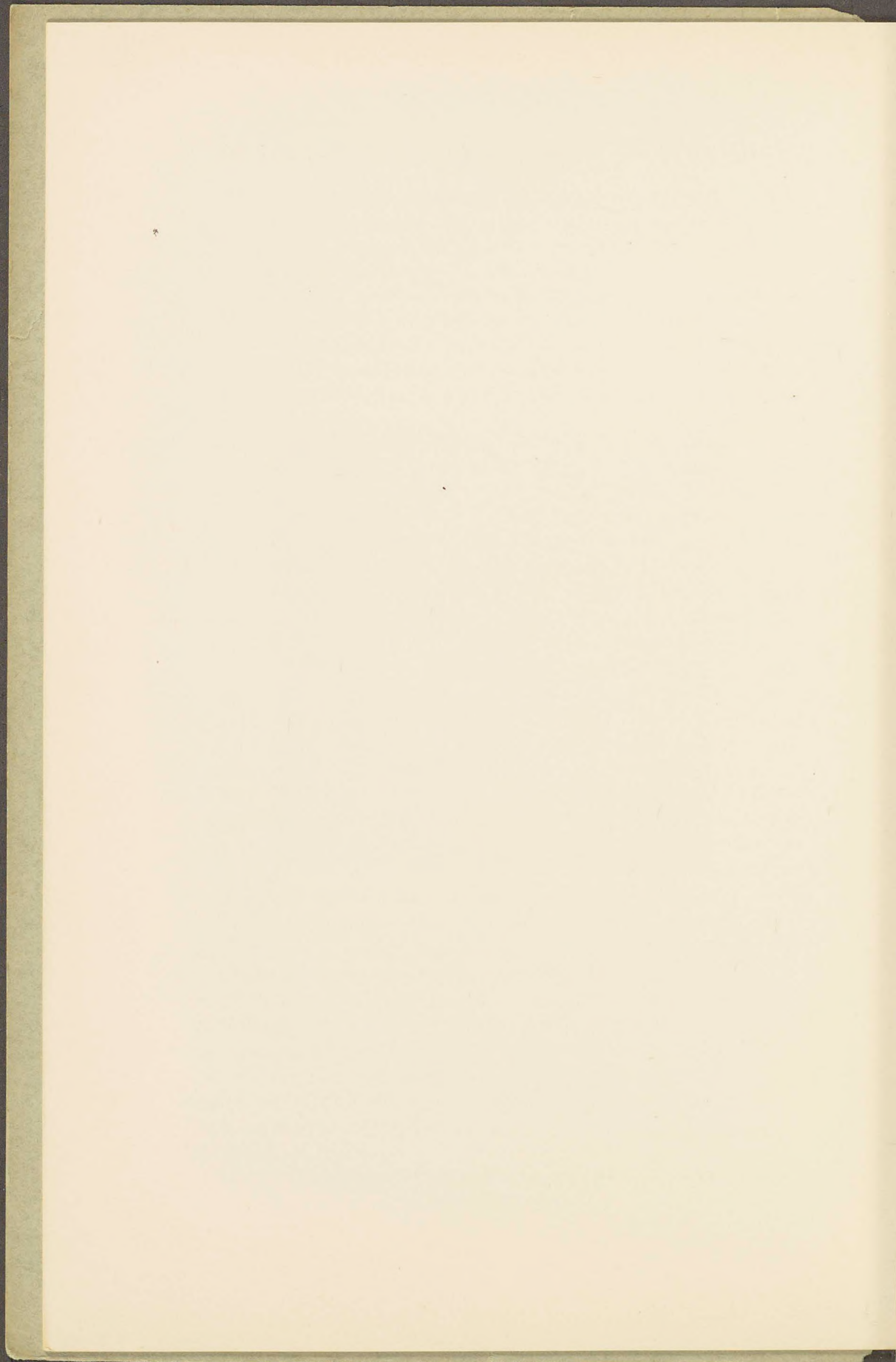
Carbonates (comprising both dolomite and calcite) are always in evidence. They exhibit no crystal form, being usually in rounded granules enclosed in serpentine. They also fill small fissures. Chromite is rather more abundant than in the Staten Island specimens. It is perfectly fresh and exhibits the usual metallic lustre and crystal form.

Talc and chlorite with small amounts of iron ores comprise the the remaining components and call for no special comment.

Chemical Composition.—The similarity to the rock of Staten Island is well shown by an analysis by Mr. G. A. Goodell.

SiO ₂	36.90	MgO	23.75
Al ₂ O ₃	1.29	CaO	15.53
FeO	5.79	H ₂ O	13.14
Cr ₂ O ₃	0.45		—
FeO	1.46	Total	98.31

(To be continued.)



THE SERPENTINES OF MANHATTAN ISLAND AND VICINITY AND THEIR ACCOMPANYING MINERALS.

By D. H. NEWLAND.

(Continued from page 317, Vol. XXII.)

THE NEW ROCHELLE SERPENTINE.

Geological Relations.—About one mile from the New Rochelle railway station, on the northern shore of Davenport's Neck, there is a small but interesting body of serpentine, which is mentioned in Mather's report and which has been described briefly by J. D. Dana* and F. J. H. Merrill.† According to Dana the serpentine lies along the axis of an anticlinal that widens out in a northerly direction. He believes it to be closely related to limestone and to owe its origin to the alteration of included silicates, especially pyroxene. Merrill states that he found crystals of bronzite and actinolite in the process of serpentinization. The question of genesis is discussed at considerable length by him, with important results, of which the following is a brief extract: "In all probability the magnesian silicate rocks, which by their alteration have yielded these serpentines, were similar in their origin to the amphibolites and pyroxenites which abound in Westchester county. * * * In composition the amphibolite and pyroxenite beds of the Manhattan group bear the same relation to the strata which enclose them as the intrusive mass of the Palisades bears to the beds of sandstone and arkose between which it is now included. There is nothing but their somewhat foliated condition to suggest that they are of sedimentary origin and this characteristic has been shown to result from dynamo-metamorphism."

The prevailing rock of this section is a hornblendic mica-schist of very variable composition but usually containing both quartz and feldspar in considerable amounts, besides garnet, epidote and iron oxides. The basic phases approach amphibolite. When exposed the contact with the serpentine is usually sharp. In places,

*Geological Relations of the Limestone Belts of Westchester Co., N. Y. *Am. Jour. Sci.*, III., Vol. 20, pp. 30, *et seq.*

† Reprint from New York State Museum Report, 1896, p. 30.

small veins of the latter extend into the adjacent rock but they are not continuous for any distance. They may well have been formed by extrusion of the serpentine under the pressure that was developed during alteration. In other respects also there is little geological evidence upon which to base conclusions as to the genesis or relative age of the rocks.

General Characters.—In composition and appearance the serpentine shows much variety. Carbonates are usually in evidence and sometimes form a large part of the mass. Chromite, magnetite, tremolite and discolorations of limonite may be recognized in most of the specimens. In color the serpentine varies from green in different shades to reddish or white. A peculiar mottled appearance results when bunches of iron ores and calcite alternate with serpentine.

Microscopic Characters.—A study of thin sections shows that the rock has been derived largely from a colorless *amphibole*, similar to that described in the serpentine of Staten Island. Included remnants of this mineral were frequently found and in various stages of serpentinization. The individuals are long and thinly foliated.

Pyroxene occurs in partially altered but recognizable crystals. Merrill refers to bronzite, but the writer cannot confirm this observation or the presence of any other variety of orthorhombic pyroxene. Wherever observed this mineral appeared nearly colorless and showed oblique extinction in prismatic sections. It is optically identical with the Staten Island pyroxene which has been described as diopside.

Spinel is one of the most distinctive characteristics of the rock and differentiates it from the other outcrops. This mineral occurs abundantly in well-defined octahedra that measure 2-3 mm. in diameter. It has a bright green color and belongs to the chrome spinels. A peculiar feature noticed in most of the crystals is the inclusion of irregular grains of chromite which usually occupy the centers and which are of varying size. Whether they represent original inclusions cannot be definitely determined, but it appears more likely that they have not been formed by alteration. It is rather to be inferred from the nature of the minerals that the chromite has contributed a portion of the material that has gone to build the spinel. Other individuals when examined with low powers show a cloudiness in the central portions, which under greater magnifi-

cation is resolved into minute blades of reddish color possessing a sub-metallic lustre and medium translucency. These have rounded or rude hexagonal boundaries and appear to be arranged in lines parallel to the octahedral faces of the spinel. For the purpose of determining the nature of the inclusions a separation of the constituents was attempted. This was carried out successfully by digesting in hydrochloric acid several grams of rock which had been pulverized to a coarse size. After several treatments with acid a residue



FIG. 4. Serpentine from New Rochelle. Spinel crystals with inclusions of chromite embedded in a groundmass of serpentine.

was obtained which consisted of spinel, chromite, magnetite and silicates. The particles of magnetite were removed by a magnet and the silicates by passing the material through Thoulet's solution. The remainder, a fairly pure concentrate of chromite and spinel was placed under the microscope and the minerals separated by hand. Qualitative chemical tests on the spinel showed the presence of magnesium, iron, chromium, and small amounts of aluminum and calcium but no titanium. These results would indicate that the inclusions are some form of iron, possibly hematite. The borders

of the spinel crystals show alteration to a colorless, low polarizing mineral resembling talc.

Chromite is quite abundant, rather more so than in the serpentines from the other localities. It is usually irregular in outline, rarely showing quadrilateral boundaries.

Magnetite calls for no special comment.

Limonite is a secondary constituent resulting from the alteration of the other iron ores. It is distributed in fine particles, oftentimes so thickly as to stain the rock a bright yellow.

Zoisite was not positively identified, but it may be represented by small, brownish, biaxial crystals with high relief and low birefringence.

Calcite is always present. It occurs in the form of grains embedded in the serpentine; in larger areas made up of several crystal aggregates showing rhombohedral cleavage; and as veins of variable width and extent. Although specimens of rock may be found which approach ophiolite, in general the carbonates are of minor importance relative to the serpentine. The small embedded grains are to be regarded as by-products of the serpentinization, while the larger areas and veins have been formed by leaching of the rock by surface waters and subsequent deposition. Chemical tests show that the carbonates always contain magnesia; sometimes in sufficient quantity to be classed as dolomite.

THE SERPENTINE FROM TENTH AVENUE.

This locality is now inaccessible, but its general features have been described and placed on record. According to Gale,* the rock was formerly exposed along Tenth Avenue from 59th Street north to 63d Street in a nearly north and south direction. He mentions that the serpentine occupied several conical hills and was of variable character. Chamberlain has given the following description: "An extensive bed of serpentine lies between the Hudson River and Tenth Avenue from 63d to 58th Streets. It is usually of an olivine green color, at times nearly black. Intermixed with calcite so as to present a mottled appearance, it is termed ophiolite."

A thin section of the serpentine is preserved in the petrographical collection of Columbia University, which shows similarity to the New Rochelle occurrence. It is made up of fibrous tremolite, ser-

* Geology of the First Dist. N. Y. Geol. Survey, p. 582, 1842.

pentine and calcite. The tremolite is partially serpentinized, the edges being altered, while the central portions are still fresh and transparent. Included grains of calcite, a by-product of the alterations, and small veins of the same mineral comprise a large part of the mass.

An analysis by Dr. Thomson of Edinburgh gave the following results:

SiO ₂	44.43	FeO	9.37
MgO	28.80	MnO	1.38
CaO	5.06	H ₂ O	8.58
		Total	97.62

The similarity in composition between this and the Hoboken and Staten Island rocks is noticeable. A portion of the iron no doubt exists in the ferric condition although it is all reported above as FeO.

SERPENTINE FROM AQUEDUCT SHAFT 26.

Dr. G. P. Merrill * has given a petrographic description of this rock, found on Manhattan Island, from which the following is extracted: "This serpentine occurs in a coarsely crystalline, white, granular dolomite. It plainly originates through the hydration of a white monoclinic pyroxene showing under the microscope nearly rectangular prismatic cleavages and giving extinction angles as high as 44°. The alteration is accompanied with the formation of abundant secondary calcite. * * * Under the microscope the serpentine shows a platy, almost fibrous structure, the plates in each case lying approximately parallel with the vertical axes of the crystals from which they are derived." An analysis by Mr. Catlett showed the results below:

SiO ₂	39.92	CO ₂	1.64
Al ₂ O ₃	0.08	CaO	0.90
Fe ₂ O ₃	0.50	H ₂ O (at 105°)	1.36
MgO	42.52	Ignition	13.26
		Total	100.18

* "Notes on Serpentinous Rocks of Essex County, New York," etc., *Proceed. of the U. S. Nat. Mus.*, Vol. XII., pp. 595-600.

From the statement by Dr. Merrill that the serpentine occurs in dolomite, it appears that the relations differ from the other localities. The evidence is hardly sufficient, however, to base any conclusions as to the nature of the original rock, and unfortunately no further information is available at present.

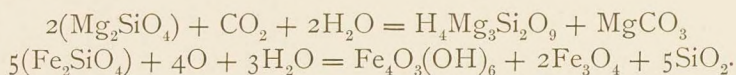
THE SERPENTINE AT RYE.

An area of several acres in the eastern part of Westchester county consists of serpentine. The exact locality is a little more than a mile north of the village of Rye and about an equal distance west from Port Chester. The outcrops, of which there are several, show the rock to be completely serpentinized and somewhat disintegrated. In thin section no clue could be found as to the origin of the mass and nothing of interest was noted. The area, like those of Staten Island and Hoboken, is lenticular.

MINERALOGY OF THE SERPENTINES.

The characteristic constituents of the serpentines have been described in the preceding pages. There is also a series of accompanying minerals, which are closely related genetically and which may be regarded as by-products, some having been derived from the alteration of the parent mass, while others owe their origin to the leaching and disintegration of the latter by atmospheric agencies.

The serpentinization of complex rocks, as these must have been, cannot take place without a dissolution of the chemical molecules and a readjustment of materials. This is essentially a process of oxidation and hydration and is accompanied by the formation of various oxidized compounds whose bases do not enter into the composition of serpentine or are in excess of the molecular proportions. In the case of olivine, an ortho-silicate of magnesium and ferrous iron, which alters readily to serpentine under natural conditions, the change may be expressed, according to Tschermak, as follows:



The equations indicate the formation of four by-products, but it seems probable that the excess of magnesia in the first will combine with the free silica to form serpentine, and it is also certain that a

portion of the iron may replace the magnesia. The processes become much more complicated when the starting point is pyroxene or amphibole, which contains lime and alumina as additional bases.

Weathering and leaching of the serpentine by ground waters contribute to the development of a third generation of minerals represented by iron ores, carbonates and vein serpentine. Iron oxides are especially susceptible to these influences. When the rock has been exposed for a long period, it has a thoroughly bleached appearance, is porous and granular, the grains of magnetite being almost completely removed. Chromite does not break up so readily as magnetite, but nevertheless, yields to the same influences.

The by-products are found in the groundmass of the serpentine, where they occur usually in granular form, in surface depressions, joints and cavities.

The following minerals are known to occur with the serpentines:

Aragonite, according to Dana,* occurs in fibrous crusts and other forms at Hoboken, no doubt accompanying the serpentine.

Asbestos.—Both varieties may be found in close proximity at Pavilion Hill. The fibrous amphibole or tremolite is distinguishable from chrysotile by its lighter color and superior hardness. The latter variety is common at Hoboken and New Rochelle. A fine specimen of asbestos with fibers nearly a foot in length was picked up at St. George, Staten Island.

Brucite occurs at Staten Island, Hoboken and New Rochelle. The first two localities are mentioned in Dana's Mineralogy, but could not be confirmed by the writer. Thinly foliated specimens of small size were collected at New Rochelle.

Calcite in granular masses is common at nearly all the serpentine localities, while small veins may be seen at New Rochelle. A specimen of serpentine from Hoboken, collected by Prof. J. F. Kemp, shows a large number of calcite crystals implanted in a matrix of finely divided carbonates. It was probably taken from the wall of a fissure. The crystals are of slender habit, being bounded by a steep rhombohedron and are much distorted.

Chalcedony is recorded by Mather as occurring at New Rochelle.† It is abundant and of a red color near Stevens Institute, Hoboken.

* "System of Mineralogy," 1900, p. 283.

† Report on the First District of N. Y., 1842, p. 426.

Chlorite has already been mentioned and described under the Staten Island area.

Chromite is described under the different localities. This mineral has been regarded as an alteration product of olivine, but such derivation seems very doubtful.

Dolomite is of common occurrence, but seldom in crystals. Beck* describes a peculiar variety from Staten Island: "Dolomite closely resembling *guruhofite* is found at the Quarantine. It is white, compact, has a flat conchoidal fracture and is so hard as sometimes to strike fire with steel. Exceedingly tough and difficult of solution, except when in a very fine powder. Sp. gr. 2.712." He gives the following analysis:

CaCO ₃	52.75
MgCO ₃	42.25
Insol SiO ₂	5.00
Iron oxide	trace
Total	100.00

Hydromagnesite.—The occurrence of this mineral at Hoboken is mentioned by Beck.† Wachminster‡ gives for its chemical composition:

SiO ₂ ,	0.57
Fe ₂ O ₃ ,	0.27
MgO,	42.41
CO ₂ ,	36.82
H ₂ O,	18.53
Loss	1.40
Total	100.00

Eliminating the small amounts of SiO₂, Fe₂O₃ and loss by ignition the molecular ratio of the remaining constituents is: MgO; 1.084; CO₂, 0.837; H₂O, 1.023. This is a close approximation of the formula, 4MgCO₃, Mg(OH)₂ + 4H₂O.

Hematite in pulverulent form is quite widely distributed, though not found anywhere in large amounts. A jasperoid hematite outcrops at a short distance from the Hoboken serpentine but within the limits of the Triassic sandstone.

* "Natural History of New York," Part III., p. 255.

† Ibid.

‡ *Silliman's Journal*, Series XVIII., p. 167.

Limonite forms extensive deposits on Staten Island and in years past has been of economic importance. The ore occupies superficial depressions in the serpentine and is never of great thickness. It has a granular or coarse oolitic structure and may be soft and earthy or cemented into compact and tough masses. The deposits have been formed, without doubt, by precipitation from chalybeate waters which have come to rest in the depressions after circulating through the serpentine. An analysis of ore from Castleton Corners, by D. J. Tysen, Jr., quoted by Dr. Britton,[†] shows the following percentages:

Fe ₂ O ₃	79.27	CaO	trace
Al ₂ O ₃	1.20	SiO ₂	5.70
Cr ₂ O ₃	1.15	H ₂ O	12.39
Mn ₂ O ₃	0.32	P	trace
MgO	trace		100.03

The presence of an appreciable amount of chromium is interesting. Abandoned limonite mines may be seen at Castleton Corners, Grant City and on the Ellingwood road.

Magnesite in massive or finely fibrous aggregates is found at Hoboken, New Rochelle, Pavilion Hill and other localities on Staten Island. Good specimens were collected from Hoboken, where it occurs quite extensively. Analyses of the mineral from this locality have given the following results:

	(1)	(2)	(3)
MgO	31.60	46.71	44.00
CaO	1.97	Trace	3.50
FeO	16.09	0.56	0.50
SiO ₂	1.17	0.23	2.00
CO ₂	49.17	50.00	50.00
H ₂ O		0.30	
Totals,	100.00	97.80	100.00

Nos. 1 and 2 are by C. A. Joy. *Ann. of the Lyc. of Nat. Hist.*, Vol. VIII., p. 122.

No. 3 is by Nuttall. *Sill. Journal*, Vol. IV., p. 17.

Magnetite is common in the form of irregular grains or small octahedra. It is mostly if not entirely a by-product, separating

[†] "The geology of Richmond Co., N. Y.," *Ann. of the N. Y. Lyc. of Nat. Hist.*, Vol. II.

out during the alteration of the primary components, more especially amphibole and olivine.

Quartz is found only along fissure or joint planes and on the surface of the serpentine. Good crystallized specimens were picked up at several localities on Staten Island where it occurs in company with the limonite beds. The crystals are small and show the ordinary prism faces terminated by $\pm R$.

Serpentine.—Various, more or less distinct varieties of minerals may be included under this caption, all of which are similar in composition and approach ordinary serpentine in other respects. *Antigorite* is a thin lamellar variety, with greasy feel, found at New Rochelle, Hoboken and Staten Island. *Bowenite* is possibly represented by a massive, pale mineral found in small veins at New Rochelle. It has a hardness of 4.5–5 and resembles common opal in appearance. Splinters fuse to a white bead before the blow-pipe. In thin sections, it is seen to be built up of round or oval granules showing concentric structure. The centers are amorphous or crypto-crystalline, while towards the periphery they are crystalline and polarize feebly. The outer layers are composed of minute fibers arranged radially and with parallel extinction. Unlike ordinary serpentine the axis of least elasticity of the fibers is at right angles to their length. Its chemical similarity to serpentine is shown by the following analyses:

SiO ₂	44.38	44.80
Al ₂ O ₃	0.22	0.12
FeO	1.17	1.02
CaO	1.05	0.93
MgO	40.29	41.05
H ₂ O	13.33	13.54
Total,	100.44	101.46

Deweylite, an amorphous, resinous variety is reported by Prof. D. S. Martin as occurring on Staten Island. The mineral contains more water than ordinary serpentine; its formula according to Dana may be $H_4 Mg_4 (SiO_4)_2 + 4H_2O$. *Marmolite*, thin foliated serpentine with pearly luster and light green color is found at Hoboken.

Talc is widely distributed, but rarely in quantity. Talcose bands intermixed with serpentine and chlorite may be observed at Pavilion

Hill, Grant City and Hoboken. The Grant City locality is probably the one referred to by Dana * as affording detached masses of foliated, snow-white talc.

Hydrous Anthophyllite may be included in the list on account of its historical interest, the type locality being at Tenth Avenue. It was formerly supposed to be a distinct mineral species, but Gratacap established its identity with tremolite in process of serpentinization.

ORIGIN OF THE SERPENTINES.

The derivation of the Staten Island, Manhattan and New Rochelle serpentines from anhydrous, magnesian silicates including pyroxene, amphibole and olivine is established by the presence of these minerals in varying stages of alteration and by the structural characters observable in most of the specimens. As to the nature of the parent rocks, however, further than their mineralogical composition, very little information is obtainable from microscopic study. The processes of serpentinization have nearly reached completion, while the original arrangement of the constituents has been obliterated by powerful dynamic forces. Nevertheless, there are a number of considerations brought out in the preceding pages, which, when compared with the results obtained in fields more favorable for investigation, indicate that the original rocks were of igneous character and allied to the pyroxenites and peridotites, rather than that they were impure limestones, as has been believed by some geologists. These considerations may be stated as follows:

1. The lenticular form of the areas and their relative elevation are characteristics usually associated with igneous intrusions. Limestones even when impure disintegrate rapidly and had they been subjected to the action of weathering and erosion it is certain that they would have been worn down to a much lower level, relative to the surrounding schists. In form the areas are analogous to the more or less serpentinized pyroxenites and peridotites that have been described from a great number of localities in the Atlantic coastal plain.

2. Their position is difficult to explain by the sedimentary theory, as Dr. F. J. H. Merrill has remarked. Such a rapid and violent change in the conditions as would lead to the deposition

* "System of Mineralogy," 1900, p. 680.

of basic magnesian rocks, when before and after them there were long periods in which strata of acid aluminous type were laid down, is not in accordance with our knowledge of sedimentary processes.

3. It is contrary to general experience that impure limestones yield by alteration a uniform mass of silicates and such uniformity is necessary to explain the sameness in character which the serpentines exhibit wherever observed. Throughout the extensive area of Staten Island, comprising a surface of 12-13 sq. miles, there appear to have been no silicates present other than pyroxene, amphibole and olivine.

4. Chromite has rarely if ever been noted as a constituent of serpentines whose origin can be traced to sedimentary rocks. From the observations of Voigt* it would further appear that this mineral may be regarded as an absolute criterion in determining the genesis of serpentines, since it is a primary constituent of eruptive magmas. J. H. Pratt † has recently advanced this theory in connection with chromite deposits of North Carolina.

5. The chemical composition of the serpentines is similar to that of pyroxenites.

AGE OF SERPENTINES.

It is impossible to fix any close limits upon the age of the serpentine bosses. The most that can be shown with certainty is that they are older than the Triassic sandstone and of more recent origin than the Manhattan schists which are now recognized as metamorphosed Hudson River strata. From present conditions it would appear that the original rocks were coarsely crystalline and had cooled at considerable depths. The parallel structure and frequent jointing show that they were under great pressure at one time, but there is no evidence of any recrystallization and they must have been unaffected by the dynamic forces which brought about the transformation of the sediments. The sequence of events was substantially as follows: (a) Deposition of sediments, (b) Metamorphism, (c) Intrusion of pyroxenites, (d) Orographic disturbance, (e) Denudation and appearance of bosses in their present position. This is in agreement with the outline of the origin of the New Rochelle serpentine as given by Dr. F. J. H. Merrill.‡

* *Zeits. f. praktische Geologie*, 1894, pp 384-393

† *Trans. Am. Inst. Min., Eng.*, Feb. 1897.

‡ *Op. cit.* p. 42

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Nos. 59-64 in preparation.

[The Flora of the Amboy Clays, by JOHN STRONG NEWBERRY, a posthumous work edited by Arthur Hollick; Monographs of the United States Geological Survey, Vol. XXVI. 4to, cloth, 260 pp., 58 pls., Washington, 1895 [1896], may be obtained for \$1.00, by addressing the Director of the United States Geological Survey, Washington D. C.]

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